THE MORRISON SHALES OF SOUTHERN COLORADO AND NORTHERN NEW MEXICO.

OUTLINE.

I. Introduction.
   1. General statement.
   2. Work previously done, areas examined, etc.
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II. Places examined.
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      b. Discussion of formations.
      c. Exeter sandstone.
      d. Unconformity at the base of the shales.
   2. Canadian canyon.
      a. Detailed section.
      b. Discussion of formations.
   3. Apishapa Canyon
   4. Foothills region.

III. Summary and conclusions.
   1. The shales of the whole region form a stratigraphical unit.
   2. The shales belong to neither the Dakota nor the Red Beds.
   3. The relation of the shales to other formations.
   4. The possible connection between the Morrison and the Lower Cretaceous.
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THE Morrison formation is known as the Atlantosaurus beds, the Como, and the non-marine Jura. It is a persistent formation composed of colored clay-shales which contain varying amounts of impure sandstones and limestones. Its maximum thickness, so far as known, is about 400 feet, but the average thickness seems to be between 200 and 300 feet. It has an extensive distribution, but the limits are unknown. It occurs in the Black Hills, and has been reported from various parts of Wyoming. It is found over a large part of western Colorado, where it is known as the Gunnison, and outcrops east of the

Rocky Mountains throughout Colorado. Until recently the formation has not been known east of the foothills region of the Rockies, although it was supposed to extend for some distance underneath the younger formations of the plains.

During the past year, 1901, I have been interested in pushing an investigation of this formation as far as possible to the east and south in the hope of finding its limits in these directions; and in the hope also that some light might be thrown upon the age of this formation, which remains a subject of some dispute. In a recent number of the JOURNAL OF GEOLOGY (Vol. IX, No. 4, May–June, 1901) I described certain shales found in the canyons of southern Colorado, and gave reasons for considering them as the probable equivalent of the Morrison formation. Since the publication of that article, these shales have been examined by Mr. Barnum Brown, of the American Museum of Natural History, with a view to opening bone quarries in them. After an examination of several days, Mr. Brown confirmed the opinion that the shales are of Morrison age, and stated furthermore that Dinosaur bones occur from a horizon fifty feet from the base to the top of the formation. He says in a private letter:

> I identified *Morosaurus* and *Diplodocus* vertebræ, and the lithological character of the beds is identical with those (Morrison) extending along the eastern side of the Rocky Mountains.

My present purpose is to report progress in tracing this formation still further to the east and south, where it is exposed in the canyons of southern Colorado and Northern New Mexico.

Over a large part of southeastern Colorado and northeastern New Mexico occurs an extensive uplift, which, roughly speaking, seems to be in the form of an oblong dome, whose axis lies near the Colorado-New Mexico line in the vicinity of Mesa de Maya. From the center, the strata dip more or less in all directions, unless perhaps in a southwesterly direction, where data are wanting. (It is possible that more detailed work will show that the slight southwest dip shown by Mr. Hills in his map of the El Mora and Spanish Peaks regions[1] is only local,

[1] *U. S. Geol. Surv.*, El Moro and Spanish Peaks Folios.

and that the uplift may prove to be an anticline extending eastward from the mountains, rather than a dome.) The dome, if such it be, is in general terms bounded on the north by the Arkansas River; on the west by the Rocky Mountains; on the south by the eastward flowing part of the Canadian River, New Mexico; to the east the dip continues at least to Beaver county, Oklahoma.

The Dakota sandstone occurs throughout this region. It is an easily recognized formation, and conspicuous wherever exposed at the surface. It is, therefore, a convenient reference horizon. Over a large part of this elevated region — perhaps the eastern four-fifths — the Dakota is either the surface formation or lies so near the surface that it is exposed in the numerous canyons. Over the western fifth, the Dakota is buried beneath the younger formations to reappear along the mountain front in a nearly perpendicular reef known as "stonewall." The greatest elevation at which I have identified the Dakota is 6,300 feet,[1] at the point where I crossed the Mesa de Maya. Over a considerable area in the vicinity of Mesa de Maya, the elevation of the Dakota is practically the same. From this region northward there is a gradual descent until the Dakota drops beneath the younger formations near the Arkansas River.[2]

The westward dip of the strata is indicated by Mr. R. C. Hills in the geological maps of the folios just referred to. A study of these maps shows that the Dakota lies about 2,200 feet beneath the surface at Trinidad, Colo., *i. e.*, it lies 3,800 feet above sea level, while twenty-five miles to the east it lies at an elevation of 5,300 feet, and sixty miles east of Trinidad, where I crossed the Mesa de Maya, it lies at an elevation of 6,300 feet. There is then a westward dip of the strata in this region of 2,500 feet in sixty miles, or about forty-one feet per mile on the average. The dip of the strata in the southern, eastern, and

[1] See *U. S. Geol. Surv.*, Mesa de Maya Sheet.

[2] G. K. GILBERT, *U. S. Geol. Surv.*, *Seventeenth Annual Report*, Pt. II, "Underground Waters of the Arkansas Valley in Eastern Colorado," sections following p. 574.

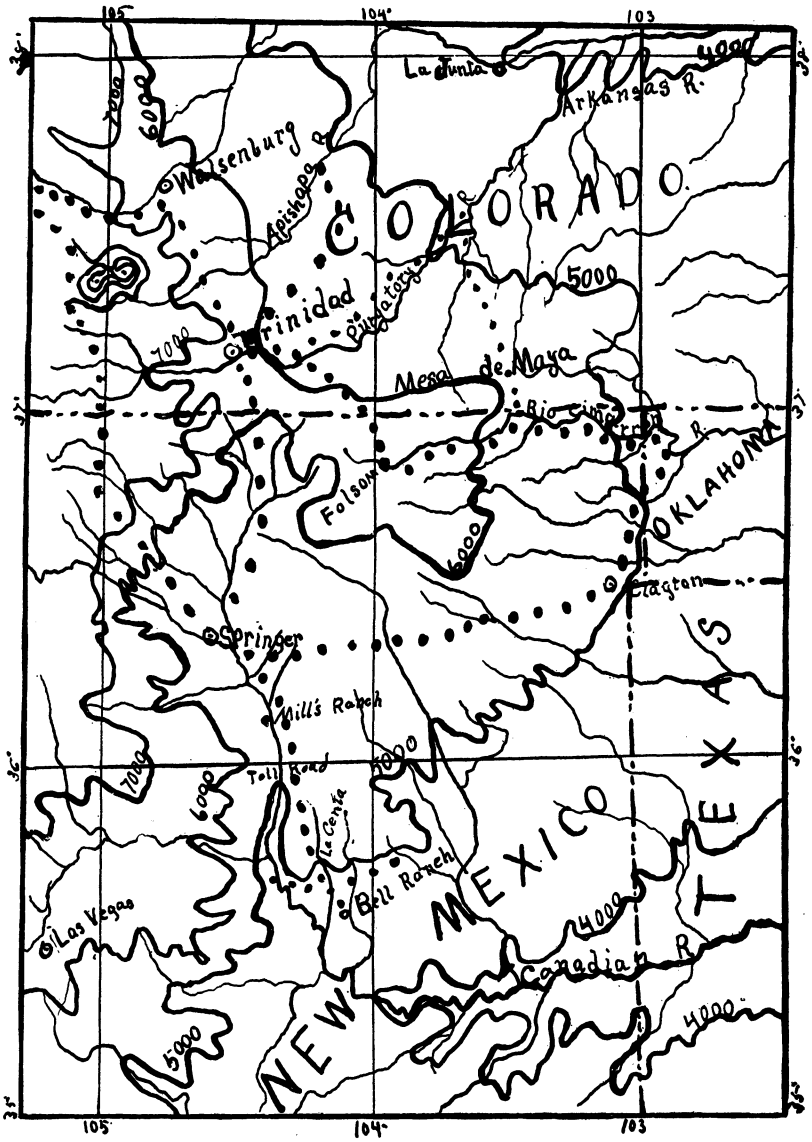


FIG. 1.—Sketch map of Southern Colorado and Northern New Mexico.

northern limbs of the uplift is practically the slope of the surface, and is indicated by the contour lines [1] of the accompanying sketch map. On these three sides, the uplift has been

[1] The contours are taken from the maps published by the U. S. Geol. Surv.

trenched by numerous streams to a sufficient depth to expose the shales which are the subject of this paper.

There is no claim advanced that this vast region has been exhaustively studied. My purpose has been to trace the shales which underlie the Dakota sandstone, over as wide an area as possible. In so doing I have visited the canyons of the Apishapa, the Purgatory, the Rio Cimarron, the Canadian, and their tributary canyons, as well as the foothills of the mountains

Dakota.	Sandstone, massive and quartzitic, somewhat conglomeratic in places.
Shales.	200 feet of varicolored shales with local beds of brittle limestone and lime concretions. A coarse, loose-textured, cross bedded sandstone occurs near the top.
Red Beds.	Deep red sandstone.

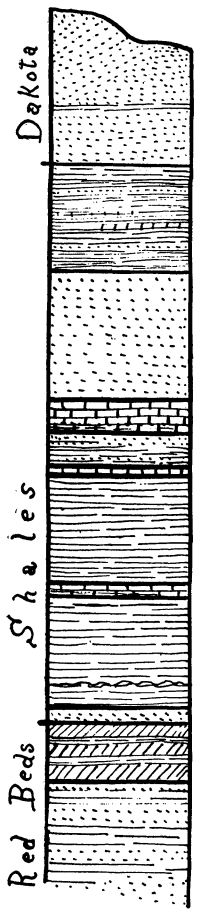
FIG. 2 (Sec. I). Taken in the Rio Cimarron, 14 miles east of Folsom, N. M.

where the sedimentary formations are sharply upturned. The itinerary is indicated by the dotted lines on the accompanying sketch map.

Rio Cimarron Canyon.[1]—There are two Cimarron rivers in New Mexico. The one referred to here, which for distinction I shall call the Rio Cimarron, flows eastward near the northern border of the territory, and finds its way through Oklahoma and Kansas to the Arkansas River. A few miles east of Folsom, N. M., the Rio Cimarron cuts through the Dakota sandstone and into the Red Beds beneath. The thickness of the Dakota was estimated at 200 feet at this point. Below this sandstone occurs twenty-five to fifty feet of soft variegated clay-shales, underneath which is a series of gypsum layers inter-stratified

[1] I am greatly indebted to Mr. T. A. Pierce for assistance in this work. He has taken an active interest in furthering the investigation.

with clay. This series in turn rests upon red sandstones of typical Red Beds type. The shales thicken from this point toward the east. In a section fourteen miles east of Folsom, the shales are about 200 feet thick. The gypsum becomes less



250 feet sandstone, massive, quartzitic, cross-bedded, slightly conglomeratic in places. A thin seam of blue clay 100 feet from the base.

40 feet colored shale containing layers of argillaceous sandstone and limestone.

50 feet coarse grained loose textured sandstone.

10 feet conchoidal limestone with clay and coarse sand at the base.
10 feet arenaceous shale.
1 to 3 feet conchoidal limestone.

40 feet variegated shale.

3 feet argillaceous limestone.

40 feet shale containing irregular seams and masses of agate-like concretions, colored in varying shades of blue and pink.

5 feet sandstone.
20 feet gypsum interbedded with clay.

—— red to purple sandstones and shales.

FIG. 3.—Section 2, in the canyon of the Rio Cimarron east of Long Canyon.

important eastward and is absent in places, as shown in the detailed sections on opposite page.

Still further to the east, below the junction of Long Canyon and the Rio Cimarron, an isolated mesa stands in the midst of the canyon. The sides of the mesa are well exposed and the

out-cropping edges of the formations easily accessible. The upper member of the Red Beds at this point is gypsum. Between this and the Dakota which caps the mesa, occurs about 200 feet of variegated shales containing a subordinate amount of sandstone and impure limestone, as shown in the accompanying detailed section, Sec. 2.

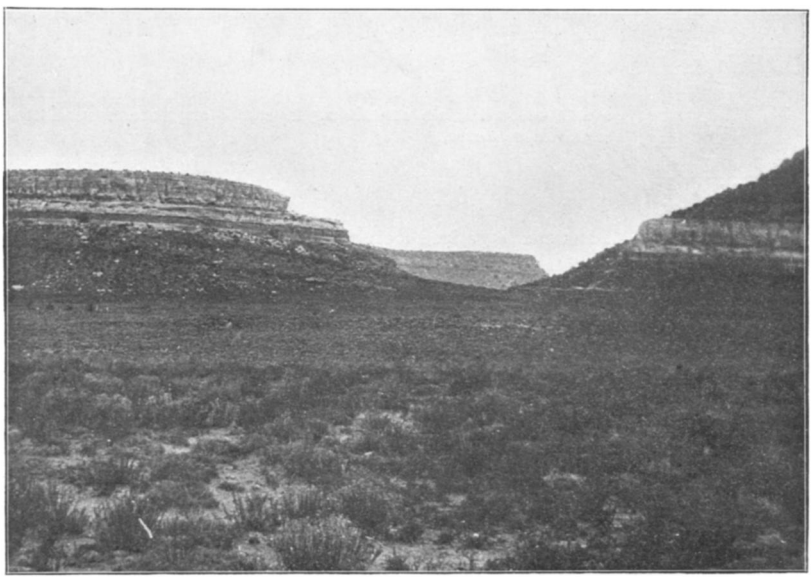


FIG. 4.— Photograph taken near Exeter post-office, N. M., showing the Exeter sandstone at the top of the butte, lying unconformably upon red beds.

The next section taken was a few miles east of Exeter post-office. Numerous buttes and mesas, varying in size from small mounds to table lands many acres in extent, have been left standing in the midst of the canyon in this vicinity. They rise abruptly from the broad, well graded bottom which is several miles wide at this point. The larger mesas are capped by the Dakota sandstone, while the smaller ones have lost their protecting caps. On the butte, shown in the photograph, Fig. 4, the Dakota and the underlying shales, have been removed. They appear however in the point shown at the right in the

photograph, where the third detailed section was taken. The cap rock of the butte is the Exeter formation, to be described beyond. In this region it immediately underlies the shales in place of the gypsum which is absent. No detailed section was taken east of this point, but the outcropping edges of the formations were seen continuously in the canyon sides to a point about seven miles east of the eastern boundary of New Mexico, where the eastward dip of the strata carries the shales beneath the canyon bottom.

In the section east of Exeter, the Dakota rests upon a series of variegated clay shales which contain layers of sandstone and impure limestone, and at this point the limestone attains greater importance than at other places examined in the Rio Cimarron. The brown limestone near the base resists erosion to such an extent that a shelf often several rods wide is produced in the canyon side. In the concretionary limestone near the top was found the only invertebrate fossil obtained from the shale formation of the Rio Cimarron. It is a fragment of a pelecypod too poorly preserved to identify.

The formations represented in the detailed sections, with the exception of the Exeter formation, to be described later, were traced continuously from Folsom eastward to a point seven miles beyond the boundary of New Mexico. The canyon sides are steep and well exposed throughout this distance and no difficulty is encountered in following the outcrops. Throughout this distance the Dakota sandstone forms the protecting rim of the canyon walls, while the middle portions of the walls are as uniformly occupied by the shale formation. This middle formation consists mainly of clay shales of various colors, and friable sandstones, varying from nearly pure silica to various admixtures of clay and sand. In certain places, however, the sandstones are hard, coarse, and slightly cross-bedded. The character of the formation varies laterally within short distances. The limestone which forms a subordinate amount of the formation, may occur at any horizon. The layers are generally less than one foot thick, and never, so far as observed, attain a thickness of

more than a few feet. They vary in character from brittle masses often of a reddish-brown color, to seams of tough admixtures of clay, lime, and sand. All of the members of this formation vary laterally in character and thickness. No two sections exhibit the same order of succession nor the same relative proportion of materials.

There is, however, one feature which is remarkably persistent, and which may deserve special mention. Near the base of the formation occurs a curious nodular seam of silica resembling imperfectly formed agates. These are sometimes loosely held together, with clay filling the internodular spaces, and sometimes gathered into a compact mass. Calcite is also found imbedded in the silica. The silica is obviously a deposit from solution. In many instances it shows a concentric structure with bands of different colors. The color varies from deep red to light blue. The seams bearing this agate-like material are usually only a few inches thick. Either the seams themselves or "float" from them were noted at nearly every point examined in the canyon of the Rio Cimarron, as well as at other localities to be described.

Throughout the extent of the Rio Cimarron, Red Beds occur underneath the shale formation. These Red Beds are composed principally of deep red to purple sandstones, although more or less red shale is interstratified with them. In the upper twenty-five miles of the canyon the upper member of the Red Beds series is gypsum. In the lower or eastward part the Exeter formation, to be described later, takes the place of the gypsum between the Red Beds and the shale formation, and lies unconformably upon the Red Beds.

I have previously shown[1] that the Dakota sandstone extends from the Purgatory and its tributary canyons to the Rio Cimarron and that a shale formation similar to the Dinosaur-bearing beds of the Purgatory was found beneath the Dakota. It is obvious, therefore, that the protecting sandstone of the Rio Cimarron is Dakota. No vertebrate fossils have been found in

[1] JOUR. GEOL., Vol. IX, May-June, 1901.

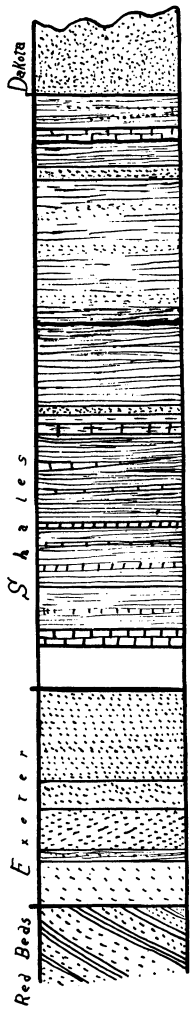
the shales of the Rio Cimarron, although ranchmen from that vicinity report having seen large petrified bones. A comparison of this formation, however, with the shale formation of the Purgatory, indicates that the two are identical in composition and stratigraphic position, and leaves little room for doubt that they are parts of one and the same formation.

In the vicinity of Exeter post-office the shales are separated from the underlying Red Beds by a well-marked unconformity. The Red Beds were thrown into gentle undulations and these undulations eroded previous to the deposition of the younger sediments upon them. Several miles west of Exeter post-office the shales rest upon the eroded edges of a local arch, from the top of which about sixty feet of the Red Beds had been removed previous to the deposition of the shales. The gypsum, which is here considered as the top of the Red Beds, appears in the flanks of the truncated arch. From this point eastward for several miles angular unconformities were noted at the top of the Red Beds. In the vicinity of Exeter, the thickness removed by erosion is considerable, but no attempt was made to estimate it. The dip of the truncated Red Beds may be estimated from the accompanying photograph (Fig. 4).

Near Exeter post-office a sandstone formation appears between the Red Beds and the shales. It lies unconformably upon the Red Beds as shown in the illustration (Fig. 4). The cap rock of the butte at the left is this new formation, which I shall for the present call the *Exeter sandstone*. It is a firm, hard and rather coarse but evenly laminated sandstone, pink to white in color. The lower strata are pink, while those above grow progressively lighter colored. It has the appearance of being composed of the coarser material from the eroded Red Beds, and may be a basal sandstone formed by the encroaching waters from the east or south, which cut away the Red Beds. The sandstone has a maximum thickness of seventy-five feet, and extends from a point several miles west of Exeter, where it thins out, eastward to the New Mexico line where it drops beneath the canyon bottom. No fossils of any kind were found in this sand-

stone. Wherever it occurs it forms a series of nearly perpendicular cliffs, thus making a broad conspicuous band along the canyon sides.

It is evident, then, that the shale formation rests in turn (1) upon the gypsum conformably; (2) upon the gypsum and the underlying Red Beds unconformably; (3) upon the Exeter sand-



78 feet of hard quartzitic sandstone.

10 to 15 feet of shale, arenaceous in places.
6 inches lime concretions.
8 feet red shale.
4 feet sandstone.

50 feet sandstone and shale (débris covered in places).

30 feet dark red shale.

4 feet coarse sandstone.
2 feet blue clay.
2 feet calcareous clay.

30 feet blue clay shale with seams of limestone.

1 foot hard brittle limestone.

20 feet shale with thin seams of impure limestone.

10 to 15 feet shale with impure limestone and sandstone bands and irregular masses of agate.
5 feet hard brown, nearly pure limestone.

20 feet (unexposed).

35 feet white sandstone, massive below but passing to well defined layers above.

8 feet loose textured and readily weathering sandstone.
15 feet massive chalky white sandstone, cross-bedded and cavernous weathering.
2 feet soft shaly sandstone.
15 feet massive evenly laminated sandstone, ranging in color from red at the base to white at the top.

—— red sandstone layers interstratified with red and purple shales.

FIG. 5.—Section 3, near Exeter post-office in the canyon of the Rio Cimarron.

stone conformably. It is noted, furthermore, that the shales, as a formation, do not vary in any marked degree either in character or thickness. Whatever may have been the physical conditions prior to the deposition of the shales, it is evident that the shales were deposited over a well-graded surface. It follows also that there was a somewhat notable time-interval between the Red Beds and the shales. A part at least of this time-interval is represented by the unconformity between the Red Beds and the Exeter sandstone. It is uncertain whether there is a time break between the Exeter sandstone and the overlying shales. However this may be, the seeming conformity which exists in many places between the Red Beds and the shales is deceptive. The contact really represents the whole time indicated by the unconformity between the Red Beds and the Exeter sandstone and the time required to form the Exeter sandstone, besides the possible period between the deposition of the Exeter and that of the shales.

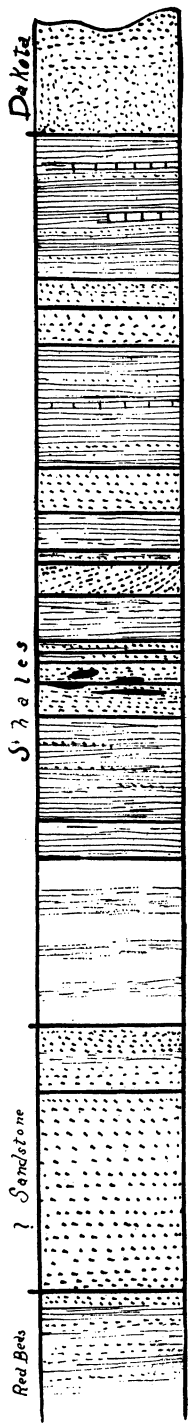
The region south of the Rio Cimarron.—In the course of the journey from the Rio Cimarron to Clayton and thence westward to Springer, no stream was found which had cut entirely through the Dakota sandstone until the Canadian River was reached. There is, therefore, a space of about sixty miles—the space by which the nearest points of the Rio Cimarron and Canadian canyons are separated—in which the shale formation was not seen. It has been penetrated, however, by wells. One well several miles northeast of the Don Carlos hills—nearly due south of Folsom—was drilling at the time I visited the region. The drill had penetrated the Dakota sandstone and was then cutting through a series of soft shales. The engineer in charge of the work described the formation as "a soft clay of different colors containing a few sand layers and thin seams of a *smooth whetrock without any grit.*" The "whetrock without any grit" was probably one of the argillaceous limestones of the shale formation.

Canadian Canyon.—The canyon of the Canadian begins where the river penetrates the Dakota sandstone a few miles south of Springer, N. M. For about fifty miles it is a narrow gorge sev-

eral hundred feet deep, but further to the south and east it widens to a broad gently inclined plain, bordered by escarpments 500 to 1,000 feet or more in height. The preservation of the escarpments is due principally to their capping of Dakota sandstone, but in some places extrusive sheets of lava form the surface rock. The canyon walls were examined at intervals as far south as Bell Ranch. From Canyon Largo, eastward, I followed along the base of the northern escarpment continuously for about thirty miles. Sections were studied, in more or less detail, at Mill's Ranch and at the toll road crossing, and at several points east of Canyon Largo. A detailed section taken at the edge of the escarpment north of Bell Ranch (Sec. 4) may be taken to represent the structure of this region. The thickness of the capping sandstone was not taken. It is the surface rock, and its thickness varies, due to surface erosion. Its original thickness does not seem to differ materially from that of the Dakota as described for the plains region in general. It was estimated at something over 300 feet. Its character differs in no obvious way from that of the Dakota described in other places. It was traced with little interruption from the Rio Cimarron to the Canadian and throughout the region examined. It is massive, quartzitic, slightly conglomeratic, and being so much more resistant than the shales and softer sandstones beneath, always forms escarpments in the regions where it has been trenched by the streams.

The lower parts of the canyon walls are made up of Red Beds. No attempt was made to study these further than to determine their relation to the overlying shales. A thickness of several hundred feet of the Red Beds is exposed where the canyon is deepest. They are deep red to purple, easily disintegrated sandstones and shales except the upper 50 to 100 feet or more in thickness. This upper series is composed of sandstones which differ so materially from the strata beneath that they may be considered as possibly representing a separate formation. They are massive, red to light pink sandstones, and form a conspicuous cliff throughout the length of the region examined.

Between the Red Beds and the Dakota occurs a shale and



250 feet sandstone, coarse, massive and quartzitic.

50 feet variegated shale containing numerous thin bands of limestone and sandstone.

10 feet argillaceous fissile sandstone.

13 feet coarse sandstone.

45 feet bluish-green shale with a few bands of sandstone and impure limestone.

15 feet coarse massive sandstone.

12 feet variegated clay shale.

5 feet white sandy shale.

13 feet coarse white sandstone, cross-bedded in places.

15 feet colored sandy shale.

6 feet argillaceous sandstone.

15 feet coarse sandstone containing lime concretions in places.

36 feet variegated shale containing thin layers of sandstone.

12 feet red and green shales.

65 feet poorly exposed. Shale seen at intervals.

10 to 50 feet rusty brown to red sandstone with bands of red clay.

50 to 100 feet massive pink to white sandstone. Forms a persistent cliff.

——Friable sandstones and shales in thin layers, red to deep purple in color.

FIG. 6.—Section 4, taken at the escarpment north of Bell Ranch.

sandstone formation approximately 300 feet thick and composed principally of variegated clay-shales and friable sandstones. Limestones of varying degrees of impurity occur with more or less frequency according to location. At the point represented in the detailed section (Sec. 4) the limestone layers are nearly all at the top. A few miles from this point a well exposed section exhibited no limestone near the top, but a stratum of bluish-green limestone several feet thick occurs near the middle. In no two sections studied do the limestones occur at the same horizon. The sandstones of this formation in the Canadian Canyon compose a notable part of the thickness (about one third to one half). The various layers differ in character from firm, well-cemented masses to beds of loose-textured sandstones which disintegrate with the greatest ease. They vary from masses of nearly pure silica through various admixtures of sand and clay to nearly pure clay. Near the middle of the formation occurs a slightly cross-bedded layer of sandstone which seems to be more persistent than the others, although this cannot be confidently stated. The shales are soft and weather readily except where they are intermingled with sand or lime in sufficient quantities to render them resistant. They are colored in various shades of red, brown, and green. In short, they differ in no obvious manner from the shales which I have already described from the canyons of the Rio Cimarron and the Purgatory.

The transition from the massive sandstone (Dakota) at the top to the shale formation is abrupt, but no definite evidence of unconformity was seen. The base of the shales is not marked here by gypsum as in the canyons of the Rio Cimarron and the Purgatory. In its place occurs the coarse, massive pink sandstone shown in the section and in the photograph (Fig. 7). No evidence of unconformity was found at the base of the shales, and the line of delimitation is drawn at the top of the heavy sandstone because of the marked change in character and composition at this horizon. No fossils were obtained from the shale formation of the Canadian, and its correlation must rest, for the present, entirely upon stratigraphic and lithologic

grounds. There is little doubt that the upper sandstone belongs to the Dakota. It is possible, however, that there may be some question regarding the lower limit of the Dakota. In the canyon of the Purgatory, the Dakota sandstone rests upon variegated shales which are in places full of Dinosaur bones. There can be

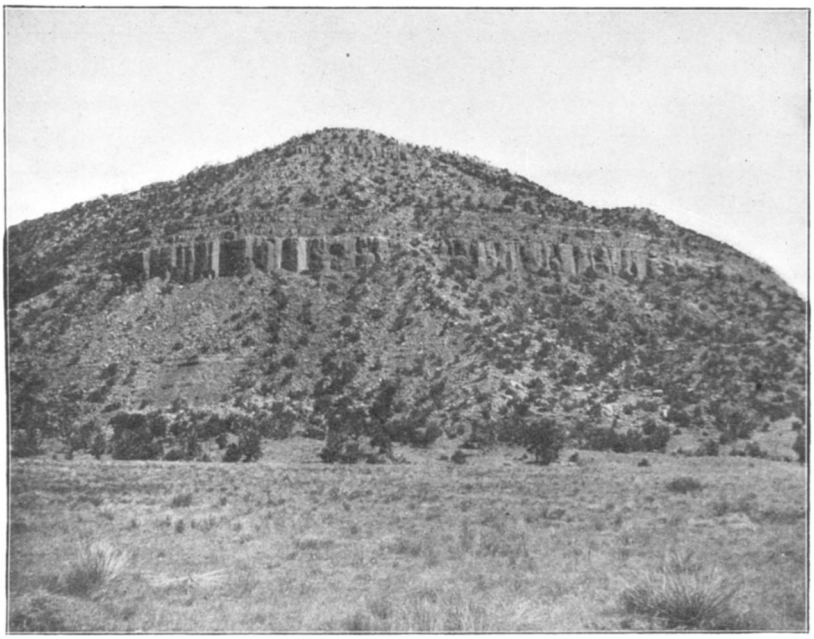


FIG. 7.— The Canadian escarpment west of La Centa Canyon, N. M. The summit is Dakota. The gentle shape near the top is occupied by the shales, with heavy sandstone at the base. The massive "columnar" layer— 100 feet thick — is the upper part of the Red Beds — the possible Trias. The lower portion is occupied by the Red Beds (Permian).

no doubt in this case as to where the line of separation should be drawn. The same change of character in passing from the Dakota to the shales obtains in the canyons of the Rio Cimarron and the Canadian. It is therefore probable that the lower limit of the Dakota is properly placed at the lower limit of the massive sandstone, and that the shale formation beneath is separate and distinct from the Dakota, although conformable with it. It is

furthermore probable that this shale formation of the Canadian is identical with that of the Rio Cimarron and the Purgatory.

Apishapa Canyon.— East of Walsenburg, Colorado, the Apishapa River cuts through the Dakota sandstone, making a sharp, narrow canyon several miles long and something more than 300 feet deep at the deepest place.[1] The greater part of the thickness exposed is sandstone. This occurs in two series separated by about 30 feet of dark colored clay-shale. The upper series forms the protecting rim of the canyon. It is about 100 feet thick, hard and quartzitic, and contains an occasional leaf impression. It weathers to a rusty brown color which seems to be characteristic of the upper part of the Dakota in this region. The lower series is massive, white, and less strongly quartzitic. In places the uneven induration permits cavernous weathering. The dark clay-shale between the two series is probably the layer of fire clay which usually occurs about the middle of the Dakota. Near Thatcher, Colorado, a few miles east of the Apishapa Canyon, fire clay is mined to some extent at a horizon which is evidently the same as that occupied by the dark shales of the Apishapa. The fire clay of Thatcher and the dark shales of the Apishapa are similar in color, character, and position, and are probably parts of one and the same deposit. Below the lower sandstone about 50 feet of somewhat highly colored shale occurs. In composition and character this shale is similar to the shales found in the Red Rocks Canyon, several miles to the east, underlying the Dakota sandstone, and are probably identical with them.[2] On the other hand a similar shale formation, and similarly placed, occurs in the canyon of the Huerfano River a few miles west of the Apishapa. The shales of the Huerfano are described by Mr. R. C. Hills in the Walsenburg Folio of the U. S. Geological Survey, and referred to the Morrison. There is little doubt, therefore, that the shales exposed in the bottom of the Apishapa Canyon belong to the Morrison.

Extension along the mountains.—Along the mountain front

[1] See *U. S. Geol. Surv.*, Apishapa Sheet.

[2] See Sec. 2, p. 347, JOUR. GEOL., Vol. IX, No. 4, May–June, 1901.

west of Trinidad, Colorado, the sedimentary formations are strongly upturned. In some places they are even overturned to such an extent that the apparent dip to the west is something like 30 degrees. A sharp "hog-back" in this region is locally known as the "stonewall." The name is derived from a quartzitic sandstone which, on account of its resistance to erosion, forms a ridge parallel to the mountain front. The serrate edge of this sandstone, which rises in places several hundred feet as a sheer wall, forms the crest of this ridge. This sandstone contains fossil tree trunks and branches. Stratigraphically above the sandstone lies a series of shales and limestones which yield fossils of Colorado-Cretaceous type. Beneath the sandstone lies a series of shales, sandstones, and limestones, which in turn is underlain by an extensive series of red sandstones—the Red Beds of the mountain front. Stratigraphically and lithologically the "stonewall" is identical with the Dakota sandstone as described from various places along the mountain front. This stonewall was traced from La Veta, Colo., southward to Gold Creek, N. M., a distance of about 40 miles.

The shale series lying between the Dakota and the Red Beds is composed principally of variegated clay-shales, with varying amounts of friable sandstones and a few thin seams of impure limestone. The best exposed section found is near the town of Stonewall, Colo., but no satisfactory place was found for making a detailed section, owing to the growth of underbrush and to the surface débris. The total thickness, where upper and lower contacts could be located, was estimated at 300 feet. The shales, sandstones, and limestones of this formation are stratigraphically and lithologically identical with those described from the canyons to the east and south. They are also identical with those described by Mr. Hills from the Walsenburg area a few miles to the north. They were identified on the north fork of the Purgatory, at the town of Stonewall, and at Gold Creek, N. M. There are strong indications that the shale underlies the Dakota continuously throughout the length of the region examined along the mountains.

Summary and conclusions.—It seems evident from the foregoing data that the shales lying beneath the Dakota sandstone in this region are found, with little variation in thickness or character, from the foot of the Rocky Mountains eastward to Oklahoma and southward to the Canadian River wherever streams have cut deep enough to expose them. This persistency in thickness and general character exhibited by the shales wherever exposed, forces the conclusion that the formation was originally continuous, at least over the area represented by the accompanying map, and leads naturally to the inference that it extends far beyond these limits. The absence of paleontological data from the New Mexico areas leads to doubt concerning the integrity of the formation over the whole area. In the absence of such data, we must resort to stratigraphic and lithologic proofs. Since the shales lie between the Dakota above and the Red Beds beneath with apparent conformity except in the canyon of the Rio Cimarron, it may not be evident to those unfamiliar with the field relations that they compose a formation distinct from the Dakota on the one hand and the Red Beds on the other. In the Purgatory Canyon the contact is sharp between the Dakota sandstone and the Dinosaur bearing shales. In the Rio Cimarron and Canadian canyons there are equally sharp contacts between the upper sandstone and the underlying shales, and these are lithologically identical with the Dakota and the shales of the Purgatory. There is, therefore, little probability that the shales belong to the Dakota.

There is even better evidence that they do not belong to the underlying formations. In the Purgatory and Rio Cimarron canyons they are separated from the Red Beds formation by a gypsum series which is here considered as representing the closing stage of the Red Beds period. As already stated, there is in the Rio Cimarron an angular unconformity between the shales and the Red Beds where the shales are seen resting upon the truncated edges of the upturned gypsum and underlying red strata. Where the Exeter formation occurs, the shales overlie it conformably, but the marked contrast between the two series

leaves little room for doubt that they are two distinct formations. A similar contrast is apparent in the canyon of the Canadian and the exposures along the mountain front. There is little doubt, therefore, that the shales are separate and distinct from the Red Beds.

Wherever the shale formation was found in this region its character is the same. Minor variations occur constantly within the formation, which in themselves constitute one of its most persistent features. The clay-shales vary laterally, as well as vertically, through arenaceous shales to sandstone on the one hand and through calcareous shales to pure limestone on the other. The members of the formation, however, are in general easily distinguished from the Dakota above and from the Red Beds beneath. There are wide areas within the region in which the shales are not exposed. But their lithological character wherever seen leads to the inference that throughout the region examined the shale series is one and the same formation.

The age of the formations underlying the shales is not definitely known. The Red Beds along the base of the mountains have been called Triassic by many geologists, while some portions at least have been referred to the Carboniferous by others. The Red Beds of the Purgatory Canyon seem to differ in no essential manner from those near the mountains, unless it be in the greater massiveness of the upper series—the upper 100 to 200 feet of the Purgatory Red Beds being massive sandstone. The Red Beds of the upper Rio Cimarron seem to be indentical with those of the Purgatory and the mountain front. Those of the lower Rio Cimarron are less massive, and composed of thin seams of red sandstone interstratified with red to purple shales. In this respect they resemble the lower series of the Red Beds exposed in the Purgatory.[1] The unconformity at the summit of this series indicates that the upper portion of the Red Beds has been removed. The Exeter sandstone entering from the east or south and thinning towards the west lies unconformably upon the Red Beds. The Red Beds of the Canadian, with the excep-

[1] LEE, JOUR. GEOL, Vol. IX, No. 4, May–June, 1901, Sec. 1, p. 346.

tion of the upper 50 to 100 feet, seem to be identical with the lower series of the Rio Cimarron and the Purgatory. The Red Beds of the Canadian are referred to the Permian by Mr. R. T. Hill,[1] While the age of the Red Beds is not of first importance in my present purpose, it may be noted incidentally that no distinction was found between the Permian of Mr. Hill at the south, and the so-called Trias at the north and west.

The Exeter sandstone is separated from the Permian by a time break in the Rio Cimarron. Its character and general field relations are similar to the upper massive series of the Canadian Red Beds. While there was no evidence of unconformity noted in the Canadian, it is possible that the upper series is of the same age as the Exeter sandstone. Mr. Hill, in his description of the Texas Region, speaks of a thin formation overlying the Permian which is referred to the Trias with some doubt. He says: "The existence of the early Mesozoic (Triassic) is doubtful although possible. Rocks referred to this period overlie the Permian along the western part of the Central Province, and appear in small areas around the border of the plateau of the plains."[2] The latter region embraces the southern portion of the area under consideration in this paper. It is possible, then, that the upper part of the Red Beds of the Canadian and perhaps the Exeter sandstone of the Rio Cimarron may be of Triassic age. If this be true the shale formation rests upon both Permian and Triassic rocks.

On the other hand, the Exeter sandstone may belong to a later age than the Trias. If the upper series of the Canadian (the possible Trias) represent not the Exeter sandstone, but that portion of the Red Beds removed by erosion where the Exeter sandstone now occurs in the Rio Cimarron, then the Exeter may be a younger formation—possibly the Trinity sandstone. In Mr. Hill's folio of the Texas Region he gives a "section showing the geology of the Texas region." This region embraces

[1] "Physical Geography of Texas Region," *U. S. Geol. Surv. Topographic Atlas*, p. 2.

[2] R. T. HILL, *Physical Geography of the Texas Region*, p. 3.

the exposures which I studied along the Canadian, and extends to within a few miles of the Rio Cimarron. According to Mr. Hill's section the Lower Cretaceous, consisting of the *Trinity*, *Fredericksburg*, and *Washita*, lies between the Red Beds and the Dakota. If Mr. Hill's section represents correctly the age of the formations in the Canadian valley, then the shales and possibly the Exeter sandstone must be of Lower Cretaceous age. But the shales, as I have already shown, are probably the same as the Dinosaur-bearing shales of the Purgatory. There is some probability therefore that the Morrison formation may be identical with some part of the Lower Cretaceous of the Texas region.

Correlation.—The key to the correlation of the shale formation is found in the Walsenburg area, Colorado. Mr. Hills[1] describes the Morrison of that region as a series of variegated shales, sandstones, and limestones lying between the Red Beds and the Dakota sandstone. According to his map the Morrison is found along the mountains near the western border of the Walsenburg quadrangle and in the canyons at the eastern extremity. The Morrison, as described in his folio, is identical in lithologic character and stratigraphic position with the shale formation described in this paper. In the Spanish Peaks area, bordering the Walsenburg area on the south,[2] the Morrison is also thought to be represented in the uplift at the Spanish Peaks. From the exposures mapped by Mr. Hills along the mountains it is but a few miles to the outcrops of the shale formation along the foothills previously described in this paper. The sedimentary formations, including the shales, are upturned a few miles west of the western boundary of the Spanish Peaks area, hence do not appear in the map of that region. There is little doubt that the shales which I have described as occurring as far south as Gold Creek, N. M., is a part of the southward continuation of the Morrison formation.

Starting again from the Walsenburg area, the Morrison occurs

[1] R. C. HILLS, *U. S. Geol. Surv.*, Walsenburg Folio, Colo.

[2] R. C. HILLS, *U, S. Geol. Surv.*, Spanish Peaks Folio, Colo.

beneath the Dakota in the canyon of the Huerfano River. In the next canyon to the east, the Apishapa, similar shales, and similarly placed, occur beneath the Dakota. Still further to the east and south, in the Purgatory and its branch canyons the same shale series occurs, bearing numerous Dinosaur bones of undoubted Morrison type. From thence southward to the Rio Cimarron and the Canadian the shales are lithologically and stratigrapically the same. It seems evident, therefore, that the shale formation throughout the region under consideration should be referred to the Morrison. It seems evident, furthermore, that the Morrison originally extended uninterruptedly over the entire region examined. Since no evidence of diminution in thickness was found, it is safe to assume that the formation extends eastward and southward beyond this area. Whether they extend to the south and east and merge into the undoubted Lower Cretaceous, as previously suggested, remains as yet undetermined.

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